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ABSTRACT

It is reasonable to assume that information such as the fact that "a beaver is larger than a mouse" is part of the average college student's generalized world knowledge. The present experiments examine the processes whereby new information is integrated with this type of generalized world knowledge. During the study phase of these experiments, subjects were told, for example, that "A BOQ is larger than a TOF. A TOF is larger than a beaver. A mouse is larger than a PIV." During the test phase, subjects were asked to verify sentences pertaining to this information. Some sentences (e.g., "A TOF is larger than a beaver.") were actually presented and needed only to be retrieved. Other sentences (e.g., "A BOQ is larger than a beaver.") could be deduced using just the information presented during the study phase. Finally, some sentences (e.g., "A TOF is larger than PIV.") could be deduced only by using one's existing knowledge that a beaver is larger than a mouse. The factors affecting subjects' ability to respond correctly to this latter type of question were examined. (Author)

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Incorporating New Information Into One's Existing World Knowledge

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The recent literature on memory for meaningful information has demonstrated beyond any reasonable doubt that memory is, indeed, a constructive process. Having accepted this proposition, it follows that the form in which information is stored may be quite different than the form in which that information was originally presented. Given that information is altered as part of the encoding process, one is naturally led to inquire about the nature of this alteration. This question has proven to be a very difficult one for psychologists to answer, but in recent years we have seen some progress in this regard.

Recent experiments designed to examine the structure of stored information have tended to fall into two distinct classes. In one class (typified by the classic work of Bransford & Franks), the researcher defines an artificial body of information which the subject attempts to learn during an experimental session. After learning the information, subjects are tested in an attempt to discover the form in which that information had been stored. In the second class (typified by the semantic memory literature), the researcher does not present any new information during an experimental session. Instead, he simply measures how long it takes a subject to answer a question about information which is already part of his generalized knowledge of the world. For example, subjects might be asked to determine the truth or falsity of a sentence describing a subset-superset relation like "A collie is a dog" (e.g. Collins & Quillian, 1969). Or, subjects might be asked to indicate whether or not a cow is bigger than a rat (e.g. Moyer, 1973). On the basis of subject's reaction times to such questions, along with the researcher's own intuitions about the structure of memory, theorists have developed several comprehensive models of the nature of our generalized world knowledge.

Although both of these lines of research have generated interesting and important results, the two lines have remained relatively independent. As a result, some very important questions have been ignored. One of these is the question of how subjects use information they already know to help them learn new information. How do subjects incorporate new information into their existing world knowledge? The present research addresses this question.

Experiment 1

Difficulties in Integrating New and Old Information

It seems reasonable to assume the information that "a beaver is larger than a mouse" is part of the average college student's world knowledge. In our first experiment, we presented relations which required subjects to incorporate new information in with this existing knowledge. Subjects might be told, for example, that "A BOQ is larger than a TOF. A TOF is larger than a beaver. A mouse is larger than a PIV." The relationship described by these sentences can be diagrammed as:

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BOQ____TOF____beaver . . . . mouse____PIV

Method

A mini-paragraph consisting of three sentences was printed on a CRT screen. The sentences stated the relations between a set of three imaginary terms (designated by nonsense syllables) by relating them to two real terms with which subjects were familiar (as described above). The order of presentation of the sentences was varied across paragraphs.

Subjects were given the following instructions regarding the real and imaginary terms in the mini-paragraph:

> We are interested in learning how people use what they already know to help them learn new information. When you press a button to indicate that you are ready to proceed, a mini-paragraph consisting of three sentences will be presented on the screen. Some of the terms in the sentence will represent real items which should be familiar to you. Other terms, denoted by nonsense syllables, will represent imaginary items which are unfamiliar to you.

Subjects were allowed to study each paragraph for as long as they liked. When they pressed a button to indicate that they were ready to proceed, the paragraph was erased and a series of test sentences was presented on the screen. The test sentences described a variety of relations among both real and imaginary terms. Subjects were to indicate whether each sentence was true or false.

Subjects were given the following instructions with regard to the test sentences:

> Note that the information in a test sentence can be true even though it was never explicitly stated in the paragraph. Your prior knowledge about the real items in the paragraph should enable you to deduce some relations that were not actually presented. Hence, some sentences should be considered true because the information in that sentence was actually presented in the paragraph. Other sentences should be considered true because the information described in them could be deduced from your existing knowledge about real things in the world.

After subjects had responded to all the test sentences pertaining to the first paragraph, they were given feedback indicating how accurately they had responded. Then a second paragraph was presented. This cycle was repeated until subjects had responded to a total of 11 paragraphs. The first paragraph was treated as a warmup and was not scored.

There are several interesting test sentences based on the relation:

BOQ____TOF____beaver . . . . mouse____PIV

Three relations were actually presented. These were "BOQ-TOF," "TOF-beaver," and "mouse-PIV." One relation could be deduced using only the presented information. This relation was "BOQ-beaver." Finally, some relations could not

be deduced without using one's existing knowledge of the world (i.e. the knowledge that "A beaver is larger than a mouse"). We tested three of these relations; "BOQ-PIV," "TOF-PIV," and "TOF-mouse." Hence, there were a total of seven true test sentences for each paragraph. A corresponding set of seven false sentences were constructed by reversing the order of the true sentences.

It should be clear that there is a control problem in the experiment as described above, for the different types of sentences also differ in the specific terms used and in the placement of those terms in the ordering. Previous research (e.g. Potts, 1972; Potts, 1974) has shown that with material such as this there is a definite advantage for the first end-term in the ordering. To eliminate this type of problem, two different types of paragraph were used. One type described the relation:

(1) BOQ_____TOF_____beaver . . . . mouse_____PIV

while a control paragraph described the relation

(2) BOQ_____beaver . . . .mouse_____TOF_____PIV

Of the 10 scored paragraphs learned by each subject, half were one type and half were the other.

Examination of these two relations reveals that between them both the specific pair used and the placement in the ordering are perfectly counterbalanced between actually presented pairs and inference pairs. For example, in relation 2, "BOQ-beaver" is an actually presented pair at the beginning of the ordering while "mouse-PIV" is an inference pair at the end of the ordering. In relation 1, however, "BOQ-beaver" is an inference pair at the beginning of the ordering while "mouse-PIV" is an actually presented pair at the end of the ordering. Similar comparisons can be made of all tested pairs except "BOQ-PIV," which always represents an inference pair containing both end terms. Because of this, this pair will be ignored in what follows. For convenience, in describing the data we will refer only to relation 1. Recognize, however, that the scores given represent averages over both relation types.

Results and Discussion

Our previous research on memory for linear orderings (e.g. Potts, 1972; Potts, 1974) has consistently demonstrated that performance is substantially better on information which subjects have to deduce than on information that was actually presented. When, for example, a four-term ordering (A > B > C > D) is established by presenting only the three adjacent pairs A > B, B > C, and C > D, we find that subject's test performance on the more remote pairs A > C, B > D, and A > D (which had to be deduced from the presented information) is substantially better than performance on the three adjacent pairs that were actually presented. This finding is clearly at odds with any non-constructive theory of memory and strongly suggests that subjects do not remember the presented information as such but instead use it to construct a unified representation of the ordering itself.

If subjects in the present experiment were successful at integrating the new information with their existing world knowledge, then the material would represent a simple 5-term ordering and one would expect performance to be very good on inference questions. Examination of the first frame of Figure 1 reveals that this is clearly not the case. Though performance on false test questions is uniform (probably reflecting the fact that, when uncertain, subjects say "False"), performance on true questions which require subjects to use their existing knowledge is very poor; significantly poorer than performance on questions pertaining to the information that was actually presented.

Insert Figure 1 about here

One can, of course, question whether this really represents a difficulty in incorporating new information with old, or whether it merely reflects the fact that for some reason subjects have difficulty drawing inferences of any kind with this material. Examination of the second frame of Figure 1 reveals that this is not the case. Subjects perform quite well on inferences which do not require them to use their prior world knowledge. When the text presents all the pieces of information necessary to form an inference, performance on that inference is just as good as performance on the information that was actually presented. Hence, it seems clear that the problem was really one of a failure to integrate new and old information rather than simply a problem with the logico-deductive process itself.

Why should subjects have a problem integrating new and old information in such a simple paradigm? Perhaps we were wrong in our assumptions about the information which college students had available to them. It seemed a bit preposterous to suggest that college students might not know that a beaver was larger than a mouse, but in spite of our feelings of foolishness, we gathered a group of 40 students and asked each the eleven key questions (one for each paragraph) which we had assumed were part of their world knowledge. Except for two errors (one student felt a bus was longer than a train, another felt a mouse was larger than a beaver), all answers were correct (Whew!). We went a step farther and inserted these questions as part of the test so we could collect reaction times. Proportion correct on these items was as high as porportion correct on any of the items, and reaction times on these items were shorter than reaction times on any other items. Hence, it seems safe to assume that this information not only was part of subject's world knowledge, but was also readily accessible.

Experiment 2

The Effect of Presenting Information Which Subjects Already Know

If subject's problem in the above experiment was really one of integrating new and old information rather than a problem with the deductive process itself, then presenting the familiar information (i.e. including the sentence "A beaver is larger than a mouse" in the paragraph) should completely eliminate the problem.

Again feeling a bit foolish, we replicated the above experiment with two conditions. The "Not Presented" (NP) condition was a simple replication of the previous experiment. All paragraphs consisted of a set of three sentences listed one under the other in random order. The "Presented" (P) condition was

identical except that a fourth sentence was added to each paragraph. This sentence always followed the other three and merely stated the relation between the real terms (i.e., immediately following the three sentences was a sentence which read "A beaver is larger than a mouse.").

It seemed quite unlikely to us that such a manipulation could serve to facilitate performance to any substantial degree. By the same token, however, with that sentence included the material described a simple 5-term ordering. Given our previous results using such an ordering, it was not clear how performance on all inferences could fail to be good in this condition. Hence, neither of the possible outcomes (good performance on inferences or poor performance on inferences) seemed very likely.

Results & Discussion

The results are presented in Figure 2 and are quite clear-cut. When the real information (which subjects already know) was not presented, we once again found that performance was very poor on inferences that required the use of that information; significantly poorer than performance on the presented information. When the real information was presented, however, performance was very good on all inferences; slightly better, in fact (though not significantly) than performance on the information that was actually presented. Performance on inferences which do not require the use of the real information was, of course, good in both cases.

Insert Figure 2 about here

Experiment 3

Facilitating the Integration of New and Old Information

Experiments 1 & 2 indicate that for some reason subjects have difficulty drawing inferences which require them to integrate new and old information. This is true in spite of 1) the simplicity of the presented material, 2) extremely explicit instructions that this kind of integration was expected, and 3) the feedback given after each paragraph indicating that the subjects were making errors and hence were not performing as expected. While this difficulty seems surprising on the surface, perhaps it should not be.

Good teachers at all levels work very hard to present new information in such a way that students cannot help but see the relation between that information and some previously imparted knowledge. It is, I am afraid, an all too common experience to find that this effort is all for naught and that, though students may remember the new information, they are totally unaware of its relation to other information they may possess.

Unfortunately, the experiments described so far do not address the question of why students fail to accomplish this integration. Specifically, they do not indicate whether subjects are unable to perform this integration or whether they simply choose (consciously or unconsciously) not to. In either case, their failure to integrate is interesting, and an examination of the factors which might serve to affect subjects ability (or tendency) to accomplish this integration is in order.

We have performed a series of experiments designed to examine those factors which could serve to facilitate the integration of new and old information. It is clear from these studies that integration is affected by a variety of factors, but much more work needs to be done before we can claim to have successfully isolated the critical factors. Rather than list this series of experiments which is, admittedly, inconclusive at present, I will describe an experiment in which we arranged all the factors in such a way as to maximize integration. This experiment differed from the previous ones in three key respects. 1) The sentences in this experiment were introduced as part of a meaningful paragraph rather than being listed one under another. 2) The test materials in this experiment included terms which were not contained in the paragraph itself. In the previous experiments all terms in the test sentences appeared in the paragraph. 3) Many more real terms were introduced into the paragraph. The previous experiments employed three artificial and two real terms, making a 5-term ordering. The present experiment employed three artificial and six real terms, making a 9-term ordering. 4) Subjects were given several trials on a single paragraph.

Each subject in the present experiment learned one of two relations. These relations are shown in Figure 3. Pairwise relations that were actually presented are underlined. If an item is not underlined, it was not presented in the paragraph. The X's and Y's represent items of this type; they appear in the test sentences but were never presented in the paragraph.

If subjects successfully integrate new and old information, then comparisons involving terms which are quantitatively distant should require less time than comparisons involving terms which are quantitatively close. This follows from both our previous work on artificial linear orderings (e.g. Potts, 1972; Potts, 1974) and Moyer's (1973) work on comparisons of size relations among known animals. Both of these lines of research indicate that the time required to compare linearly ordered items is an inverse function of the distance separating them.

Examination of Figure 3 reveals that this is indeed the case. For subjects learning the top relation, reaction time to the sentence "An X (e.g., rhino, bison, moose) is larger than a FIP," which represents a small difference, is significantly longer than reaction time to the sentence "A FIP is larger than a Y (e.g., roach, termite, gnat)," which represents a large distance. For subjects learning the bottom relation, on the other hand, reaction time to the sentence "An X is larger than a FIP" is significantly shorter than reaction time to the sentence "A FIP is larger than a Y." Hence, in both cases reaction time is shorter on the larger distance. Note that, by use of the two types of relation, the actual terms used and the position of those terms in the ordering are not confounded with distance.

Insert Figure 3 about here

The above result indicates that subjects are performing as one would suspect them to if they were indeed successfully integrating new and old information, but there is one alternative explanation that must be considered. It may be that subjects are merely remembering the sentences that were presented and deducing the test information only when required. Assume, for example, that subjects had been told that "A zebra is larger than a FIP." When asked to indicate whether

a moose is larger than a FIP, they could recall that they had been told that a zebra was larger than a FIP and answer the question by recalling the fact that a moose is larger than a zebra from their world knowledge. The observed distance effect would be observed because comparing zebra to a moose is particularly difficult due to their closeness (Moyer, 1973).

If this were the case, then one would expect reaction time to any pair whose relationship was actually presented to be much shorter than reaction time to a pair whose relationship was not explicitly stated, regardless of distance. Figure 4 clearly shows that this is not the case. Reaction time to pairs whose relationship was actually stated but which are close together is substantially longer than reaction time to pairs which are far apart, even though they were not presented. This effect was highly significant in all cases and does clearly indicate that subjects are successfully incorporating the new and old information.

Insert Figure 4 about here

Practical Implications

Integrating New and Old Information. One of the key goals of education is to teach students to integrate new information into their existing world knowledge in such a way as to allow the two bodies of information to interact and generate inferences that were not originally part of either body of information. Too often, teachers find that this goal is very difficult if not impossible to reach. The present experiments represent a first attempt to examine the problems involved in reaching this goal.

The present paper describes two basically similar paradigms, one of which yeilds very poor integration and one of which yields very good integration. Some of the factors which differentiated these paradigms were 1) whether the information was presented as individual sentences or as part of a meaningful paragraph, 2) the proportion of new to old information, 3) the presence of test items which were not included in the paragraph, 4) the amount of exposure to the presented information. Further research will be required to determine the relative importance of these factors in facilitating the process of integrating new and old information.

Methodology. As noted in the beginning of the paper, research designed to examine the structure of stored information has fallen into two classes, one of which examines performance on a body of artificial information learned during an experimental session and one which examines subject's ability to retrieve information from their existing world knowledge. Both paradigms have their limitations. The present paradigm represents a hybrid which enables us to gain some of the benefits of both paradigms while eliminating some of their major pitfalls.

The major problem with studies of semantic memory is the unavoidable introduction of confounds due to the fact that the experimenter's choice of material is limited to information that is available in a subject's memory. Hence, these studies are basically correlational in nature and, as every student of introductory experimental method knows, one can never escape all possible confounds in a correlational study.

The use of artificial information acquired during an experimental session avoids this problem for it enables the experimenter to control the instructional history of the material being used. Unfortunately, use of this kind of material too often leads subjects to adopt special strategies for performing in the experiment. Consequently, it is often hard, if not impossible, to generalize one's conclusions beyond the immediate experimental procedure.

The present paradigm, while not eliminating either all confounds or all artificiality, is helpful in both respects. Note that in the present experiments, even though subject's real world knowledge was tapped, the effects tested were not confounded by the specific item pairs used. For example, in one condition the sentence "A moose is larger than a FIP" represented a small semantic distance. In another condition, however, this same pair of terms represented a large distance. Hence, the introduction of artificial terms enabled us to control for item effects while still using subjects real world knowledge.

Similarly, when using only artificial information, the test items one uses must be drawn from the body of information presented. For example, in our original linear ordering experiments we were forced to test only among all possible pairwise relations within the presented ordering. Since subjects quickly learn the set of possible test items, this naturally tends to foster the adoption of special strategies for dealing with this information (cf., for example, the end-term processing strategy adopted by subjects in the experiments reported by Potts, 1974). The introduction of real terms along with the artificial information enabled us to ask questions employing terms which were never presented in the paragraph. For example, we could reasonably ask a subject if a moose was larger than a FIP even though the term "moose" never appeared in the paragraph. Because of this, subjects had no way of knowing what test sentences we were going to ask. This could not help but interfere with attempts to establish special strategies.

Because of these considerations, I feel that the present "incorporation" paradigm has considerable potential in a variety of areas and deserves closer examination as a research tool.

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Footnotes

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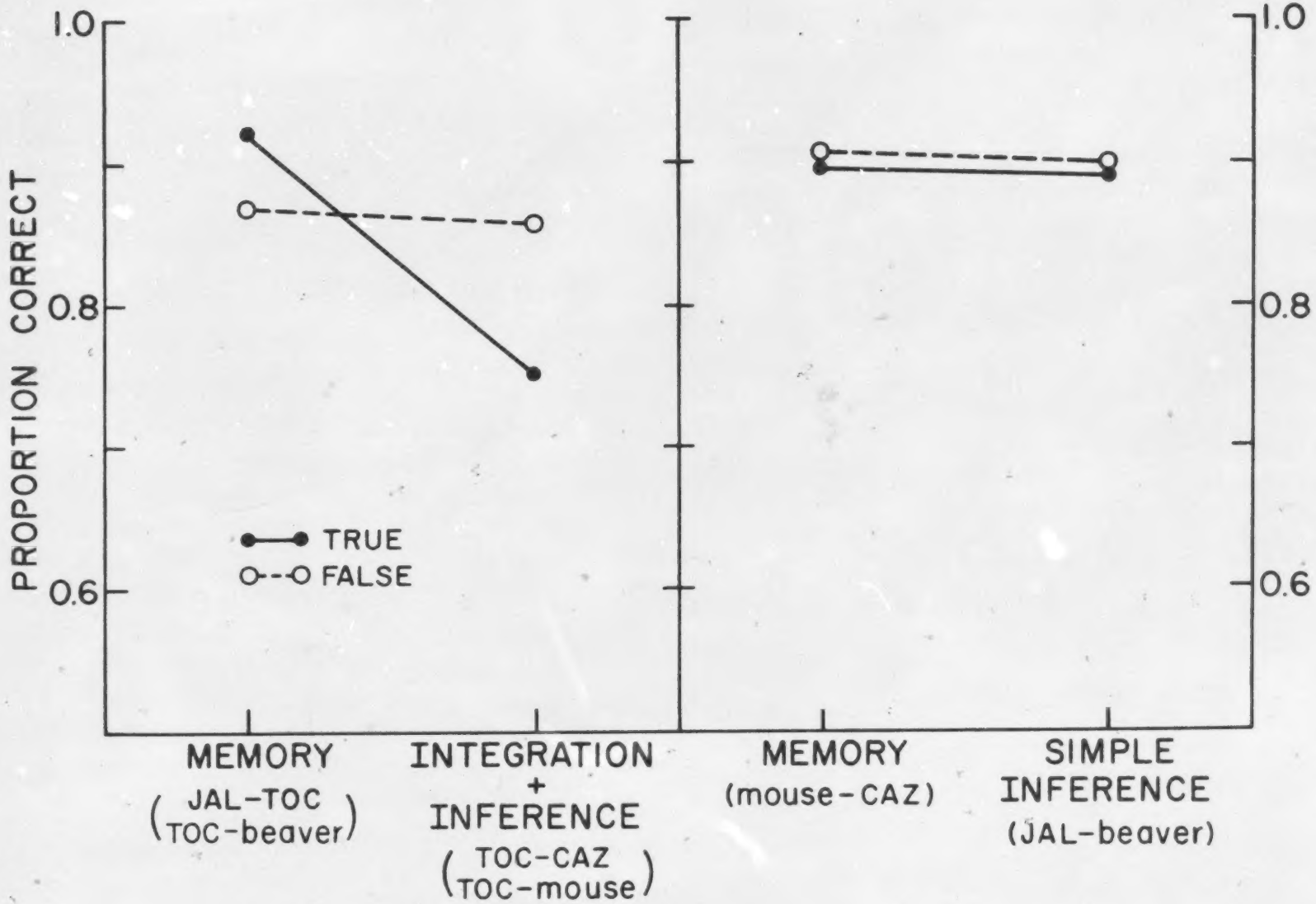

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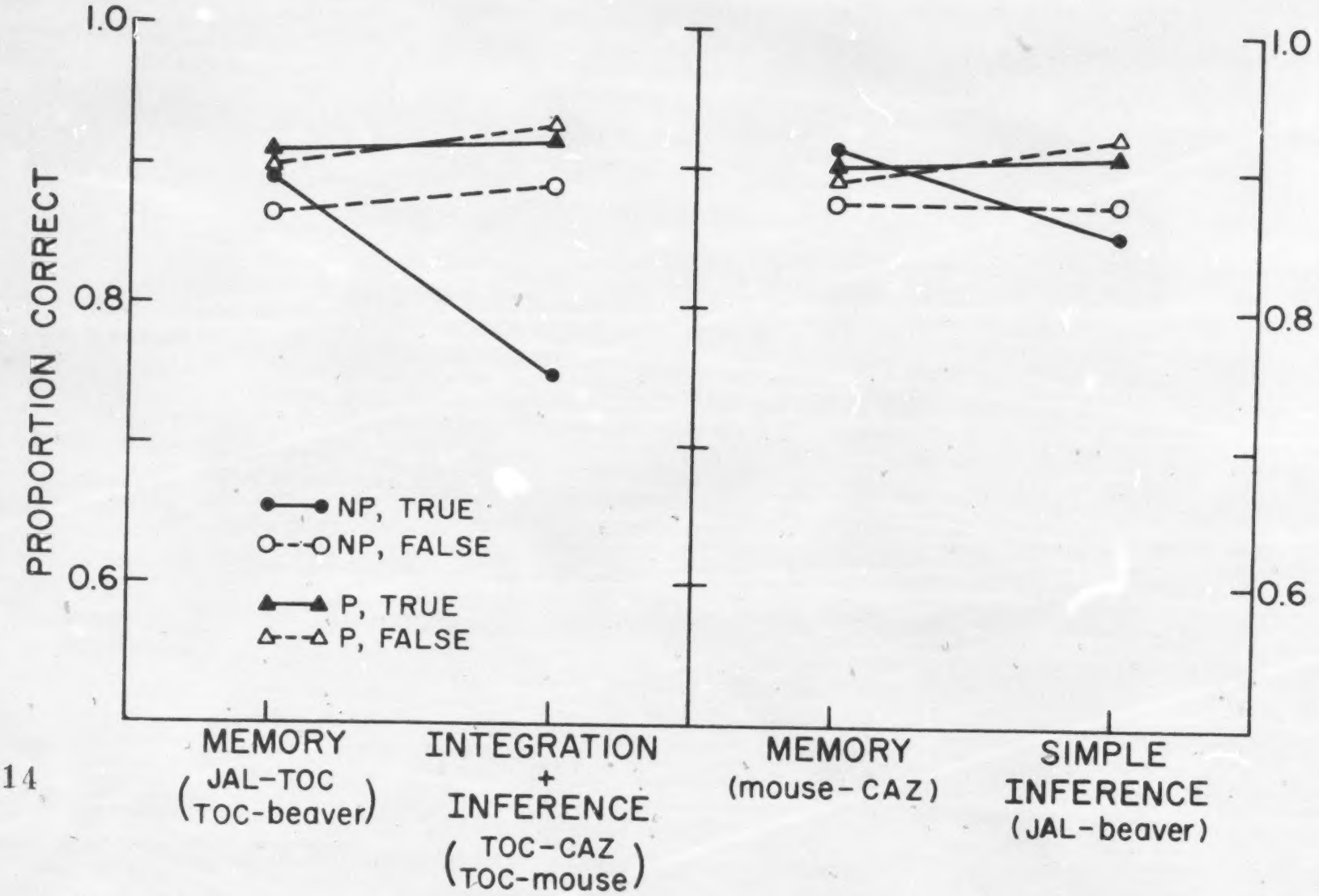

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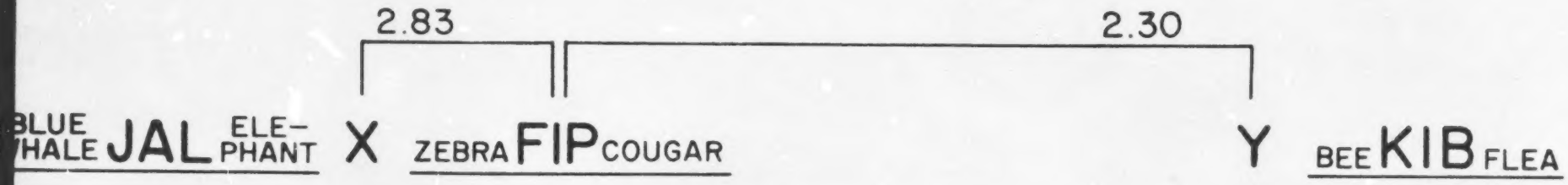
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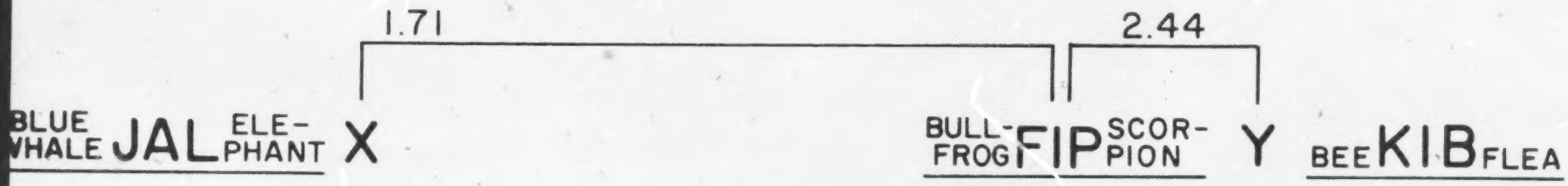
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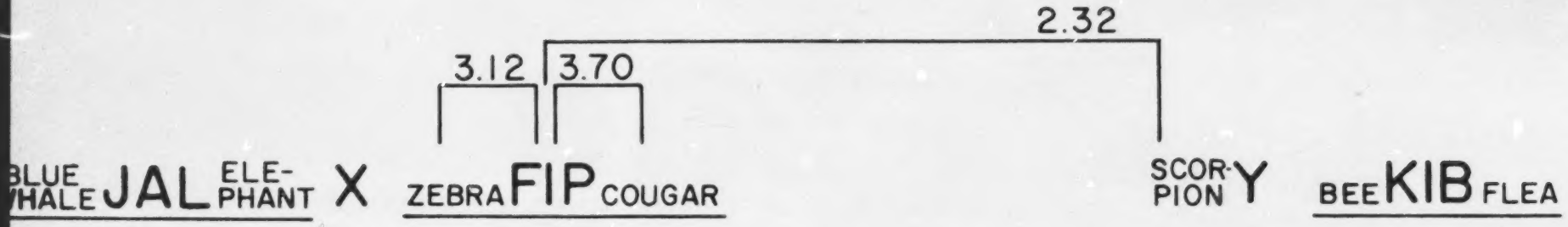
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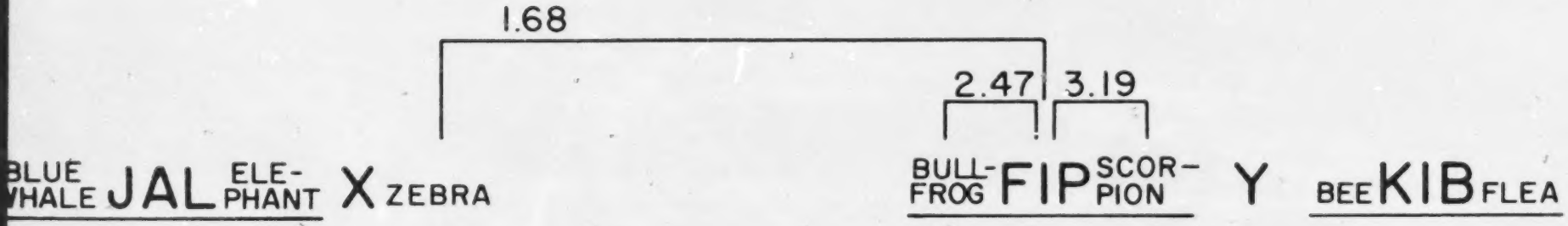
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